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A LARGE FISH KILL OF ATLANTIC MENHADEN, *BREVOORTIA TYRANNUS*, ON THE NORTH CAROLINA COAST

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Abstract: At dawn on 8 December 1997, commercial fish spotter pilots discovered an enormous school of Atlantic menhaden in the Atlantic Ocean less than 0.5 km from the beach along Core Banks, North Carolina. The school was estimated to contain up to 60,000 t of fish. Pilots observed dead or dying fish on the water's surface over portions of the school, prior to any fishing operations for the week. Crews of fishing vessels on site reported a 30 cm thick layer of dead or dying menhaden near the surface, and an enforcement officer documented dead fish that washed ashore. Scientific literature is replete with accounts of Atlantic menhaden fish kills caused by predation, parasites, and diseases. The magnitude and spontaneity of this fish kill suggest that school-induced, low-dissolved oxygen levels may have been the causal factor, while the proximity of large predators may have exacerbated the situation. An event of this magnitude, in addition to other recently-recognized sources of mortality in pre-adult menhaden, may have stock assessment ramifications that go beyond a localized fish kill.

Key words: Atlantic menhaden; *Brevoortia tyrannus*; fish kill; North Carolina.

INTRODUCTION

Atlantic menhaden, *Brevoortia tyrannus,* are moderate-sized clupeid fish that form dense, surface schools in nearshore coastal waters along the East Coast of the United States. As filter-feeding planktivores, menhaden serve as a major energy link between phyto- and zooplankters and higher trophic-level piscivorous fishes, such as bluefish, *Pomatomus saltatrix,* and striped bass, *Morone saxatilis.* During spring through early winter, schools of Atlantic menhaden are harvested by purse seines used in a reduction fishery for fish meal and fish oil (Smith, 1991). The fishery is conducted during daylight hours; spotter pilots in small, overhead-wing aircraft locate fish schools and direct the setting of the net.

Currently, the Atlantic menhaden fishery is centered in the lower Chesapeake Bay, and extant reduction facilities (two) with about 15 vessels are in Virginia and North Carolina. Annual landings of Atlantic menhaden for reduction since 1994 have averaged 280,000 metric tons (mt), a majority of which are taken from May through September in the Virginia portion of Chesapeake Bay and nearshore waters of the Atlantic Ocean north to New Jersey (Smith, 1999).

Most fish that summer north of Cape Hatteras migrate south beginning in late October around the Virginia and North Carolina capes (Fig. 1). Migratory fish in November and December often form enormous schools, composed of hundreds of millions of individuals, within a few kilometers of the shoreline (June,

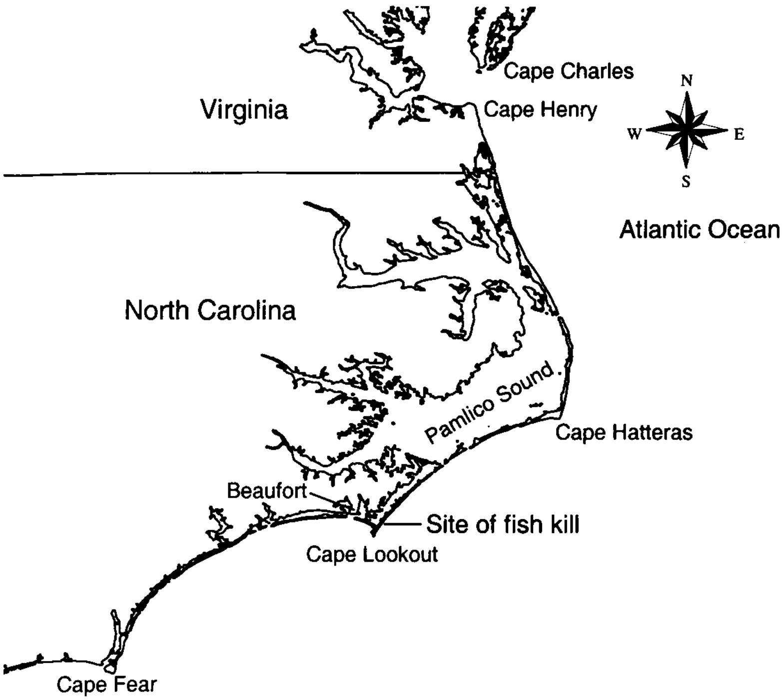

Figure 1. Coastal Virginia and North Carolina showing site of Atlantic menhaden kill on 8 December 1997, approximately 11 km northeast of Cape Lookout lighthouse along Core Banks, Carteret County, North Carolina.

1961; Smith, 1991). Median catch per individual purse seine set during fall (ca. 38 t) exceeds catches for other seasonal and areal facets of the fishery (Smith, 1999).

Scientific literature on the species, in addition to extensive life history and population studies on Atlantic menhaden, conducted primarily at the Beaufort Laboratory of the National Marine Fisheries Service (NMFS) (Ahrenholz, 1991), is replete with accounts of fish kills because of predators, parasites, diseases, or unknown causes. Goode (1879), as early as the 1800s, related numerous accounts of dead and dying menhaden driven onto New England beaches by predaceous bluefish, while additional narratives cited windrows of dead menhaden along shore, but no causative agent. Westman and Nigrelli (1955) described the "annual, heavy mortality of menhaden in the waters adjacent to New York Harbor . . . when millions of fish die and litter the beaches"; dying fish spin from lack of coordinated movement, exhibit exopthalmia, and have hemorrhaged gill, eyes, and optic lobes. Annual kills during spring in Chesapeake Bay, where dying fish whorl and spin, fostered studies by Stephens et al. (1980), who identified a virus as the cause of "spinning disease" in Atlantic menhaden. Less dramatic kills of menhaden have been attributed to parasites (Kroger and Guthrie, 1972). Reintjes (1969) cited numerous reports of mass mortalities of Atlantic menhaden from torn purse seine gear, near-freezing estuarine water temperatures, low-dissolved oxygen, and industrial pollution. Kills of Atlantic menhaden caused by "epizootic ulcerative syndromes" (=ulcerative mycosis [UM] disease) and toxic dinoflagellates have recently been described from numerous East Coast estuaries by Ahrenholz et al.,[1] Sindermann[2], Noga et al. (1991), Burkholder et al. (1992) and Faisal and Hargis (1992).

Menhaden industry personnel have reported on a few occasions since the early 1980s spectacular, autumnal fish kills of Atlantic menhaden in nearshore ocean waters along the North Carolina coast (AMAC[3]). Migrating schools of Atlantic menhaden are reported to be so densely packed that they consume all available dissolved oxygen in the water column, then "boil up" to the surface and die from anoxic conditions (AMAC[3]). Here, I report a dramatic fish kill of Atlantic menhaden in nearshore waters of the Atlantic Ocean near Cape Lookout, Carteret County, North Carolina.

OBSERVATIONS

Menhaden spotter pilots sighted at dawn on Monday, 8 December 1997, an enormous concentration of Atlantic menhaden in the Atlantic Ocean less than 0.5 km from the beach along Core Banks, Carteret County, North Carolina, approximately 11 km north of the Cape Lookout lighthouse. The pilots, who are adept at judging the size (=biomass) of fish schools, estimated the concentration to contain ca. 200 million "standard" fish (one "standard" fish in menhaden industry jargon = 250 g), or approximately 60,000 mt (Fig. 2). Movement of the fish was southwest, or "downbeach". The lead schools formed two large bodies of fish; the nearshore body was irregular-shaped measuring about 240 and 255 m at its broadest axes, and whose center was about 250 m offshore; the offshore body was elliptical, measuring 120 and 235 m at its broadest axes, and whose center was about 440 m offshore (measurements made from an overhead photograph not shown). Trailing schools of menhaden (Fig. 2) were ribbon-like, extended from the surf zone to 150 m offshore, and stretched about 0.8 km "upbeach." Depth at the farthest offshore position of the fish was about 9 m. Fathometer traces from the menhaden vessels within the schools indicated the fish were densely packed throughout the water column. Vessel crewmen suggested that the "downbeach" progress of the schools was impeded by predators such as little tunny, *Euthynnus alletteratus,* and bluefin tuna, *Thunnus thynnus,* which were known to be in the vicinity.

What made this event unique was that from the center to the fringes of the two large, offshore bodies of fish, dead or dying menhaden rose to the surface giving the areas a frothy, white appearance from overhead (Fig. 2). Menhaden fishermen reported dead or dying fish from the surface to a depth of up to 30 cm. The fish kill was ongoing from 0600 to 0700 hr, and prior to the first purse seine sets of the day (and week) by the two on site menhaden vessels whose homeport was

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[1] Ahrenholz, D. W., J. F. Guthrie, and R. M. Clayton. 1987. Observations of ulcerative mycosis infections on Atlantic menhaden (*Brevoortia tyrannus*). U.S. Dept. Commer., NOAA Tech. Memo. NMFS-SEFC-196, 28p.

[2] Sindermann, C. J. 1988. Epizootic ulcerative syndromes in coastal/estuarine fish. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-F/NEC-54, 37p.

[3] Atlantic Menhaden Advisory Committee (AMAC). 1992. Fishery management plan for Atlantic menhaden, 1992 revision. Atl. States Mar. Fish. Comm., Fish. Mgt. Rept. No. 22, 159p.

Figure 2. Aerial photograph (by Mr. Charlie Pittman, Jr.) of Atlantic menhaden in the Atlantic Ocean off Core Banks on 8 December 1997. Movement of the fish schools (dark areas along the shoreline) is "downbeach," or right to left. Foamy appearance to the two largest bodies of fish are dead and dying Atlantic menhaden on or near the surface (see text for details). Two menhaden vessels in bottom, right corner are 51 and 54 m long, and purse boats (with trailing white wake) are 12 m long. Core Sound is at top, left of figure.

Beaufort, North Carolina. Menhaden spotter pilots immediately alerted NCDMF enforcement officers of the event, informing them that the fish kill was "natural," and not a result of a torn fishing net. An NCDMF enforcement pilot flew a helicopter over the site to verify the kill, then landed in the vicinity on Core Banks. He observed dead menhaden strewn along the beach for approximately 600 m (M. Street, No. Car. Div. Mar. Fish., pers. comm.).

NMFS laboratory personnel were not cognizant of the fish kill until several days afterwards. Moreover, I was unaware that photographs of the event were available until several weeks later. However, daily logbook information (Smith, 1999) from both menhaden vessels on site (Fig. 2) recorded six successful purse seine sets between 0655 to 1634 hrs on 8 December 1997, and a water temperature of 11°C. Purse seine sets were made only on the fringes of the menhaden schools. Captains' estimates of catch per set ranged from 38–395 mt. Menhaden company records indicated that the daily combined catch for both vessels was 1,262 mt. A routine port sample (Smith, 1991), acquired at dockside from one vessel, consisted of 10 age-1 fish that averaged 161 mm FL and 68 g weight.

DISCUSSION

Water quality data were unavailable at the time of the event. Nevertheless, the enormity, location, and alacrity of the kill argue against traditional causes of mass mortality in Atlantic menhaden. Since the morning of 8 December was the fifth day of no fishing activity in the area, a torn purse seine was obviously not responsible for the kill. Human-induced pollution can probably be excluded as the cause of the kill, as the site of the event was in the Atlantic Ocean adjacent to the uninhabited Core Banks, part of Cape Lookout National Seashore. Nearest inlets, Bardens (ca. 11 km SW) and Drum (ca. 20 km NE) inlets, drain the pristine waters of Core Sound. Pathogens and parasites, such as bacteria, viruses or protozoans, are known to cause mortality in menhaden (Reintjes, 1969); however, the spontaneity and immensity of the event described herein suggest that these were not the causal agents. For example, menhaden that were inoculated with the virus that causes "spinning disease" swam in circular motions for up to five days before dying (Stephens et al., 1980). Therefore, I speculate that the fish kill along Core Banks was caused by school-induced, low dissolved oxygen conditions.

Mortality of Atlantic menhaden caused by low dissolved oxygen conditions has been observed throughout the species' range (AMAC[3]). Recent accounts of menhaden fish kills ascribed to depleted oxygen conditions and reported to the NMFS occurred in southern Maine during the late 1980s and early 1990s, when adult Atlantic menhaden were abundant in the southern Gulf of Maine (Vaughan, 1990). The scenarios usually involved bluefish or striped bass chasing a school of menhaden into a cove or small embayment. The menhaden, prevented from leaving the area by the predators, presumably consumed the available dissolved oxygen, then succumbed. Dead and rotten fish fouled localized areas in southern Maine, and negatively impacted the coastal tourist economy (Conniff, 1992).

Despite prodigal visual observations of menhaden fish kills, empirical evidence that the kills are a result of low dissolved oxygen conditions is generally lacking. Ancillary information, nonetheless, indicates that oxygen depletion within large fish schools can be substantial. McFarland and Moss (1967) recorded oxygen reductions from 22.6 to 28.8% within schools of striped mullet (*Mugil cephalus*). Oxygen declines within the schools were abrupt, rather than gradual, and oxygen reduction correlated well with school size, i.e., "large schools producing greater reductions." Oviatt et al. (1972) measured oxygen reductions of up to 12% within small schools of Atlantic menhaden in Narragansett Bay, Rhode Island.

The sheer magnitude of the menhaden schools observed off Core Banks in December 1997 argues for oxygen depletion as the causal agent of the subsequent fish kill. Assuming that the spotter pilots' estimate of school size was correct, total menhaden biomass may have been 60,000 mt, portions of which packed the available water column up to 9 m deep. Since Atlantic menhaden tend to school by size (Reintjes, 1969) and the specimens sampled from the concentration off Core Banks averaged 68 g, the total number of individuals present may have been almost 10^9 fish. Despite cool autumnal water temperatures on site (and consequent high oxygen solubility), the numbers of menhaden present suggest an exceptionally high oxygen demand on the water column. Knowing that oxygen depletion within fish schools can be precipitous (McFarland and Moss, 1967), it is plausible that this fish kill may have been caused by the depletion of oxygen within the menhaden school. Perhaps, the presence of predatory gamefish panicked the menhaden and exacerbated the situation.

Regardless of the cause, but aware that the menhaden industry has reported fish kills of this type on several occasions over the past two decades, events of this magnitude along with other confounding sources of pre-adult mortality of Atlantic menhaden may have stock assessment ramifications that go beyond localized accounts of fish kills. Could environmentally-mediated autumnal fish kills (e.g., low dissolved oxygen kills), in combination with high predation pressure on young-of-the-year Atlantic menhaden in Mid-Atlantic estuaries by resurgent striped bass populations (Hartman and Brandt, 1995) and the as yet unquantifiable effects of UM epizootics (Ahrenholz et al.[1]; Sindermann[2]; Noga et al., 1991; Faisal and Hargis, 1992) and toxic dinoflagellates (Burkholder et al., 1992), manifest themselves as poor recruitment in the menhaden stock? Since 1985, there has been a general downward trend in recruitment of age-1 Atlantic menhaden (AMAC[4]). Coincidentally, coastal observations of UM syndrome in the Atlantic menhaden population were initially made by Ahrenholz et al.[1] during the mid-1980s. Since 1994, recruitment of Atlantic menhaden has been mediocre to below average, ranging from 1.3–2.9 billion recruits/yr (AMAC[4]). Historical biostatistical data for the fishery (since 1955) suggest that despite periods of exceptionally high or low spawning stock biomass, unknown environmental factors tend to drive Atlantic menhaden recruitment (AMAC[4]).

Vaughan et al. (1986) in an analytical exercise prompted by the prevalence of UM syndrome in North Carolina waters during the mid-1980s assessed their ability to detect a reduction in a single year class of Atlantic menhaden resulting from a one-time calamitous event. They concluded that a catastrophic loss to an Atlantic menhaden year class would have to occur (greater than 50% coastwide loss in abundance) to be detectable at reasonable levels of statistical power (greater than 70% chance of detection), while subtler reductions (less than 25% loss in abundance) would probably go undetected. Perhaps, by reconstituting a coastal abundance survey for early juvenile Atlantic menhaden (cf. Ahrenholz et al., 1989), researchers could better quantify the effects of fishery-independent sources of mortality, such as natural fish kills, noxious algal blooms, predation, and UM syndrome, on incoming year classes of Atlantic menhaden.

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